

(12) UK Patent Application (19) GB (11) 2 340 304 (13) A

(43) Date of A Publication 16.02.2000

(21) Application No 9818376.7

(22) Date of Filing 21.08.1998

(71) Applicant(s)
Cambridge Display Technology Limited
(Incorporated in the United Kingdom)
181A Huntingdon Road, CAMBRIDGE, CB3 0DJ,
United Kingdom

(72) Inventor(s)
Jeremy Henley Burroughes

(74) Agent and/or Address for Service
Page White & Farrer
54 Doughty Street, LONDON, WC1N 2LS,
United Kingdom

(51) INT CL⁷
H01L 51/20, H05B 33/14

(52) UK CL (Edition R)
H1K KEAM K1EA K2R4

(56) Documents Cited
WO 95/31515 A1 JP 009219289 A US 5276381 A

(58) Field of Search
UK CL (Edition P) H1K KEAM
INT CL⁶ H01L 51/20, H05B 33/14
Online:WPI, JAPIO, EPODOC

(54) Abstract Title
Organic light emitters

(57) A light-emissive device comprising: a first charge carrier injecting layer for injecting positive charge carriers; a second charge carrier injecting layer for injecting negative charge carriers; and a light-emissive layer located between the charge carrier injecting layers and comprising a mixture of at least two electroluminescent organic materials, the relative proportions of the said organic materials in the light-emissive layer influencing the emission colour of the light-emissive layer. The light emitting layer may be configured to produce white light.

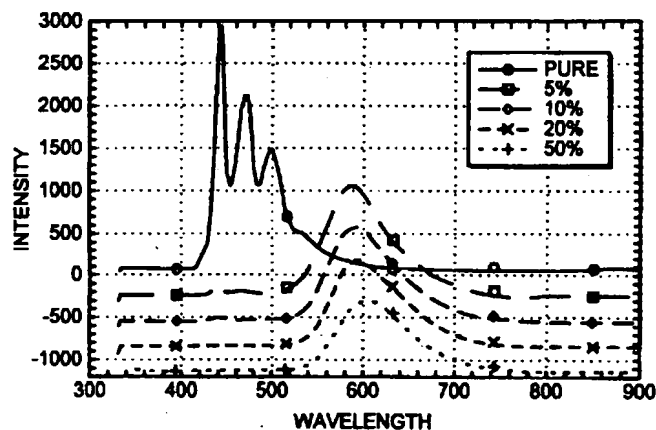


FIG. 3

GB 2 340 304 A

FIG. 2

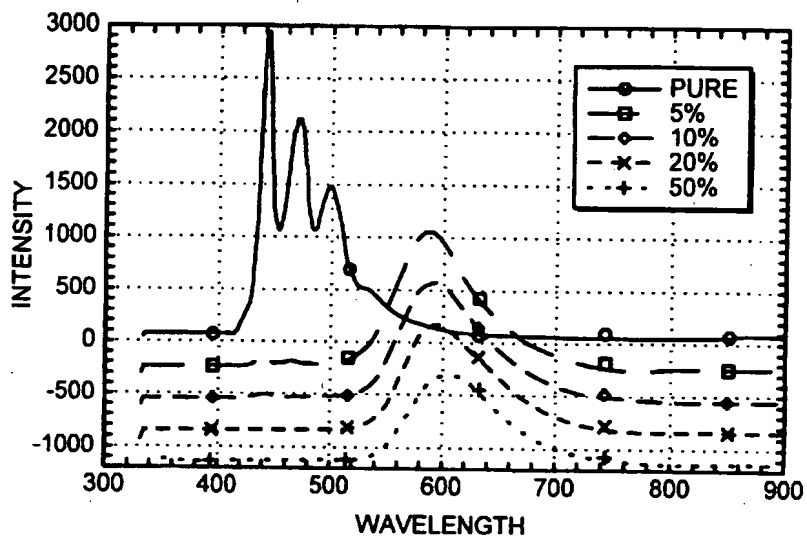


FIG. 3

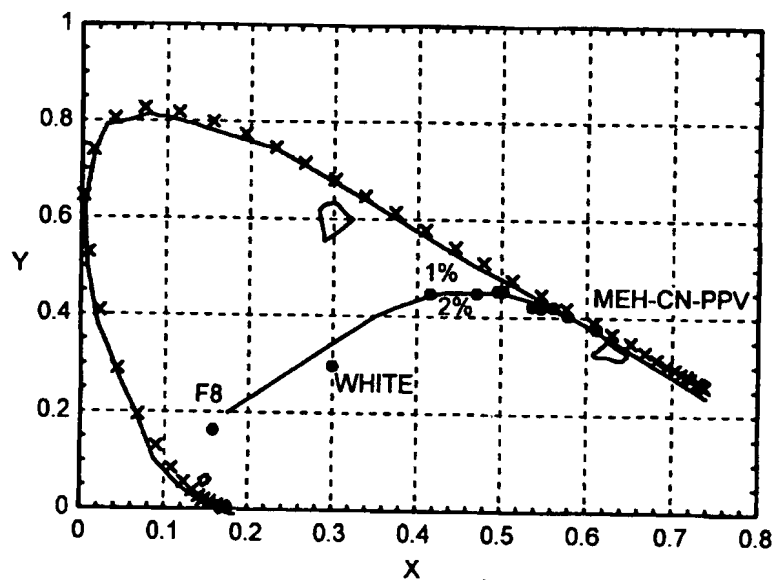


FIG. 4

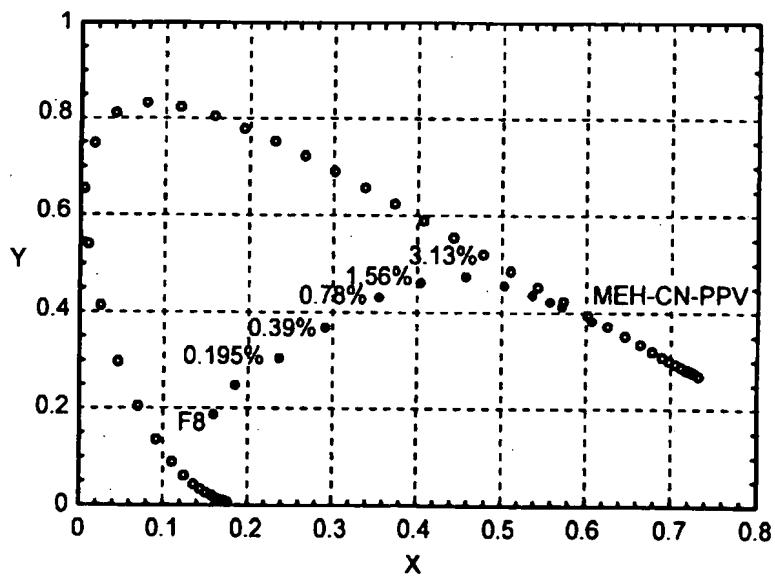


FIG. 5

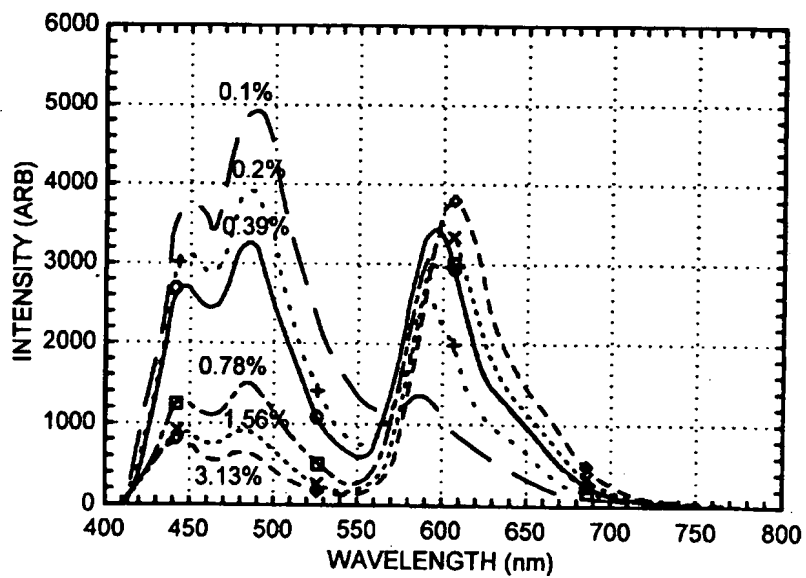


FIG. 6

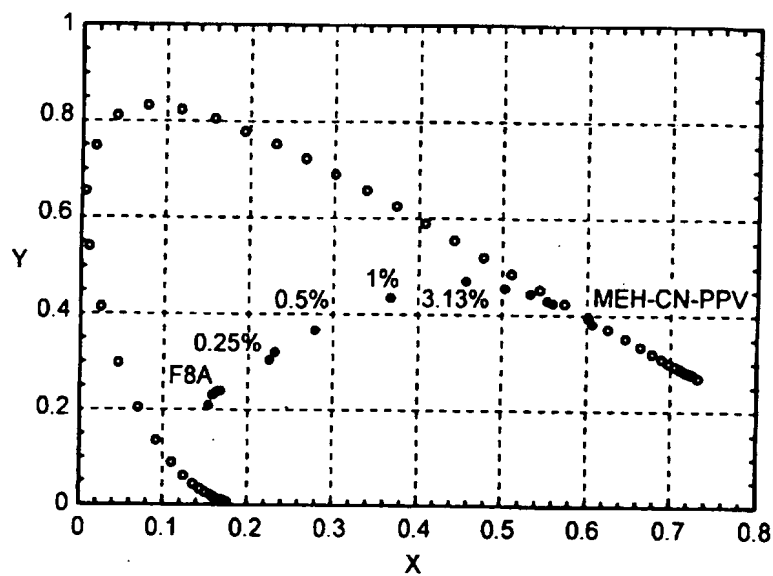


FIG. 7

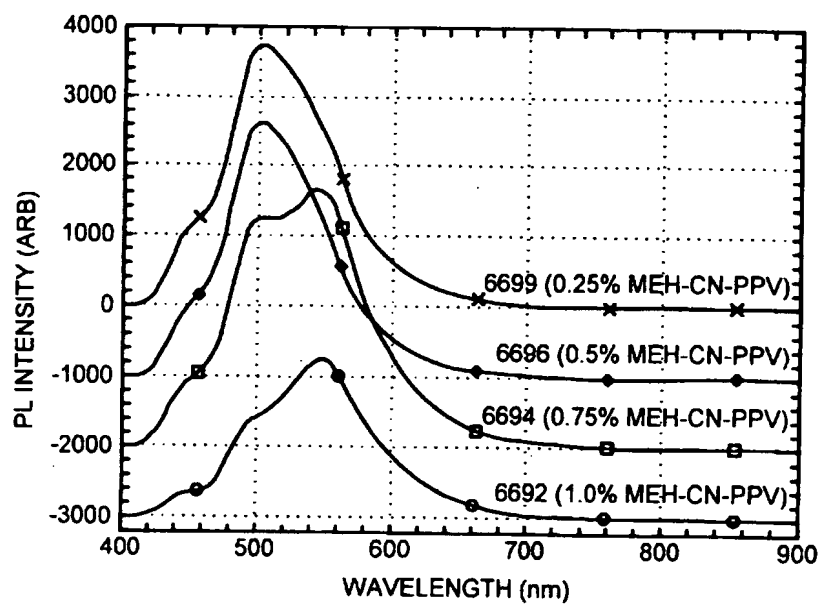


FIG. 8

5 / 12

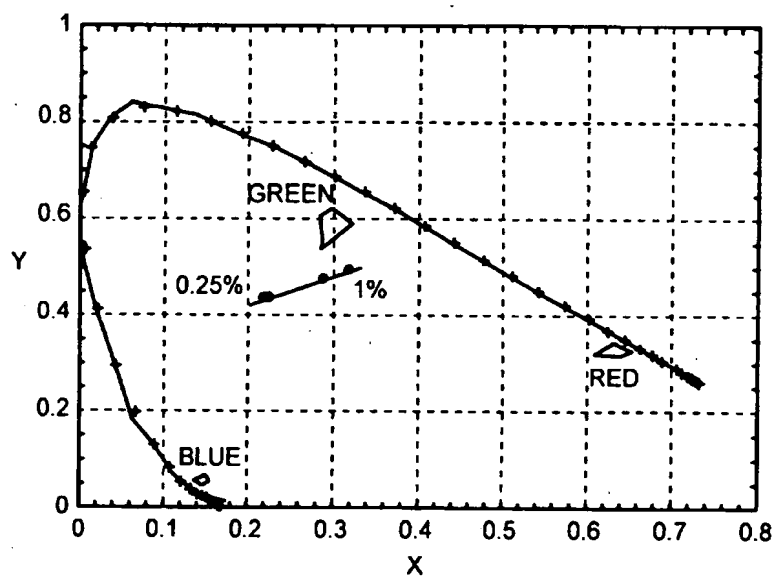


FIG. 9

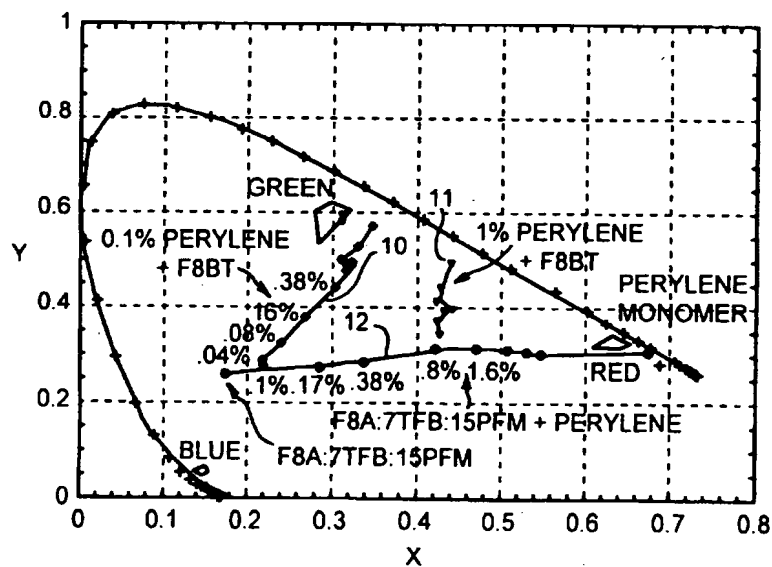


FIG. 10

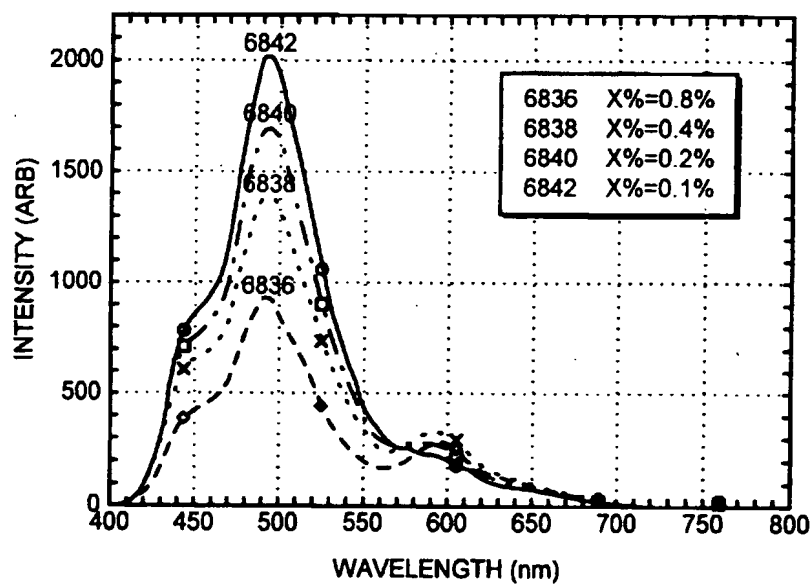


FIG. 11

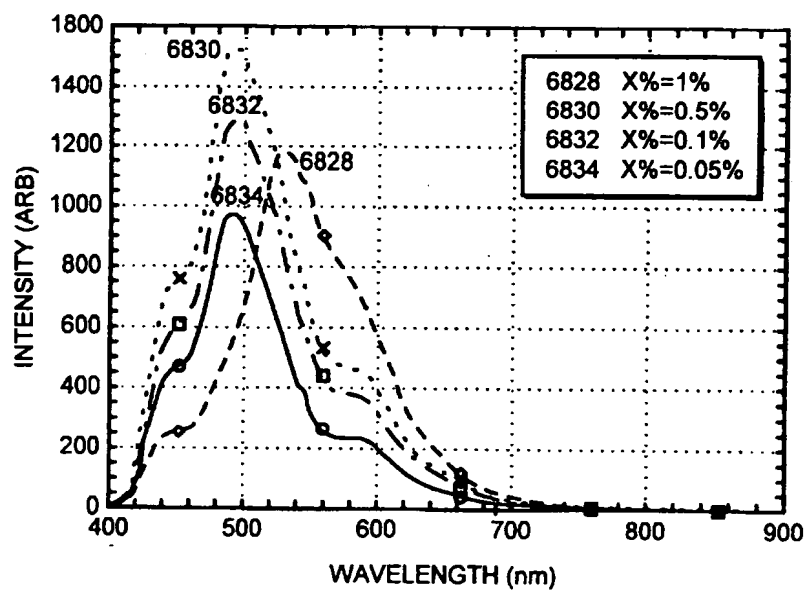


FIG. 12

7 / 12

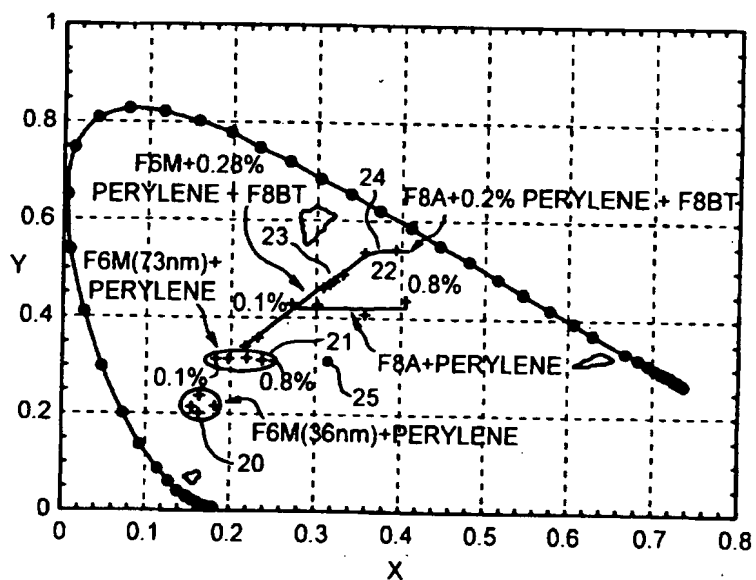


FIG. 13

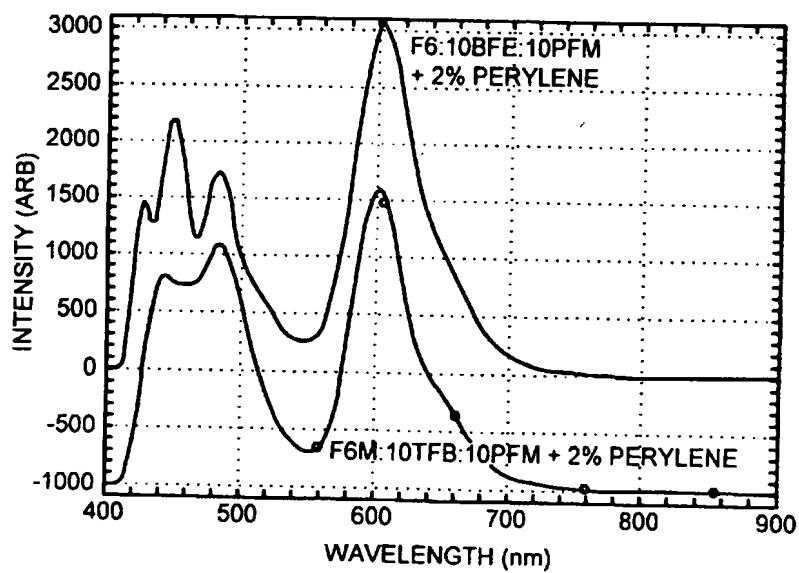


FIG. 14

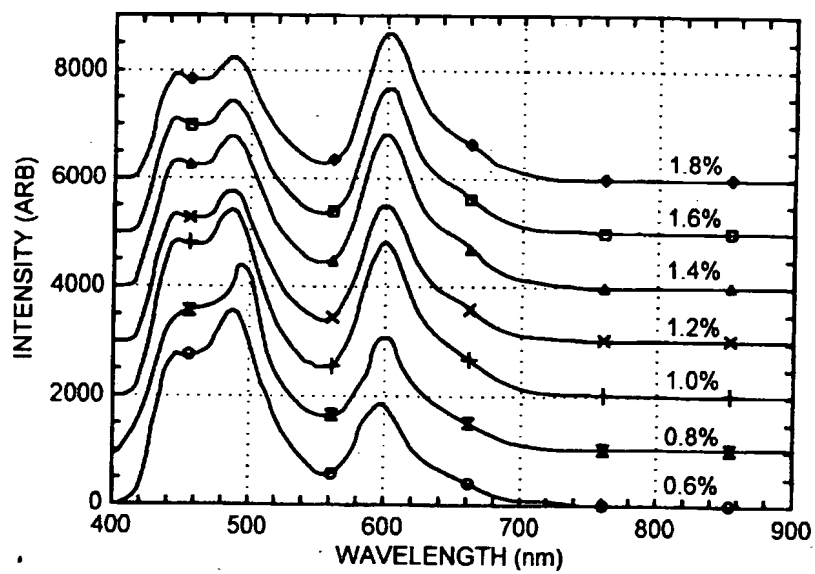


FIG. 15

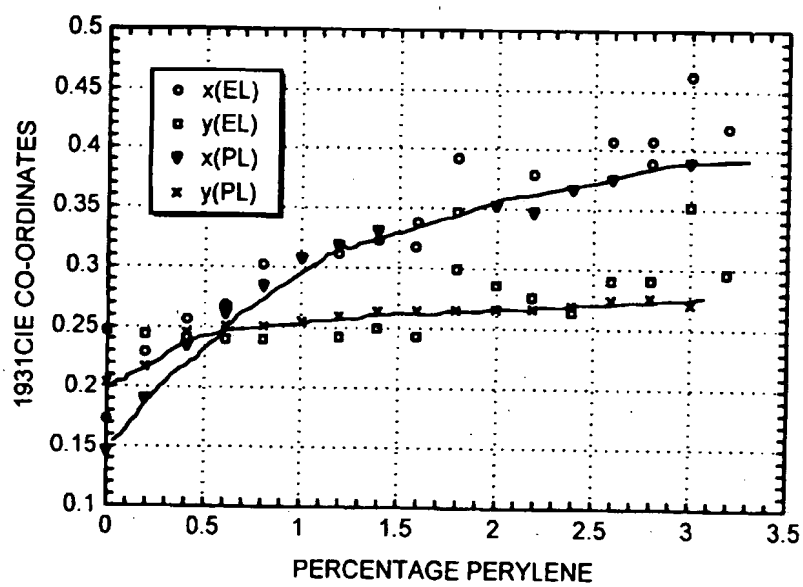


FIG. 16

9 / 12

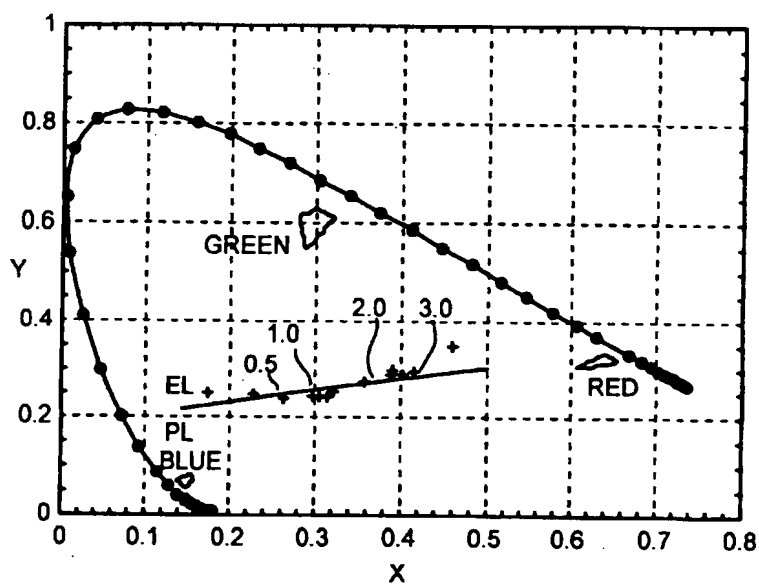


FIG. 17

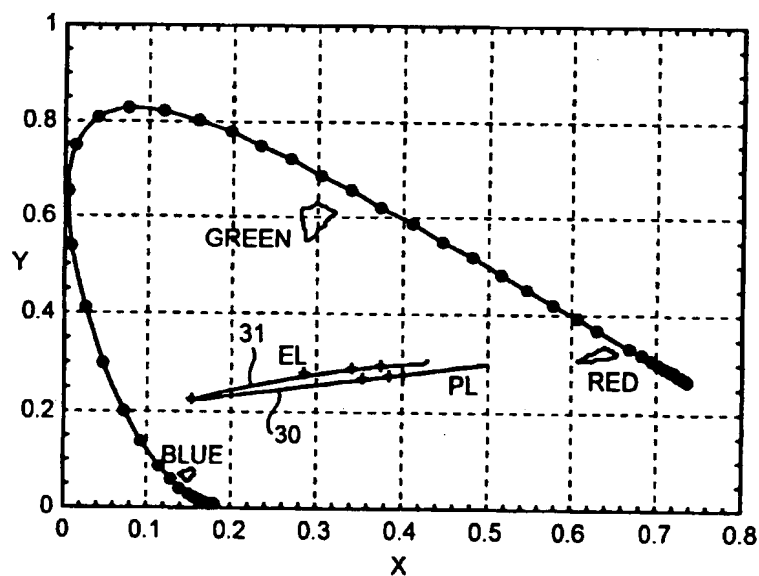


FIG. 18

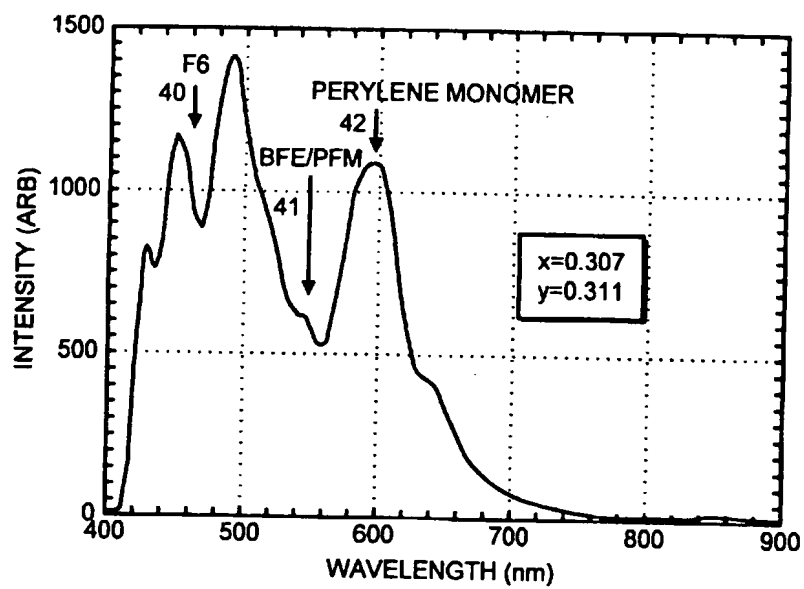


FIG. 19

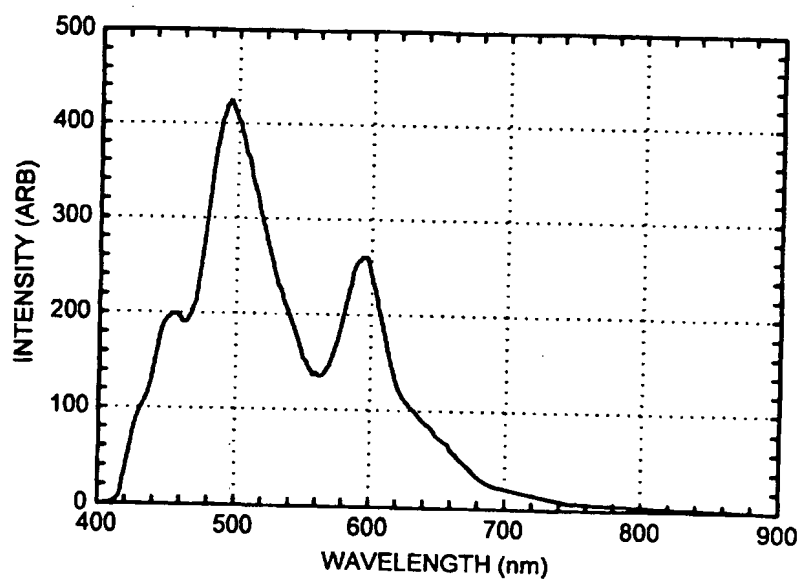


FIG. 20

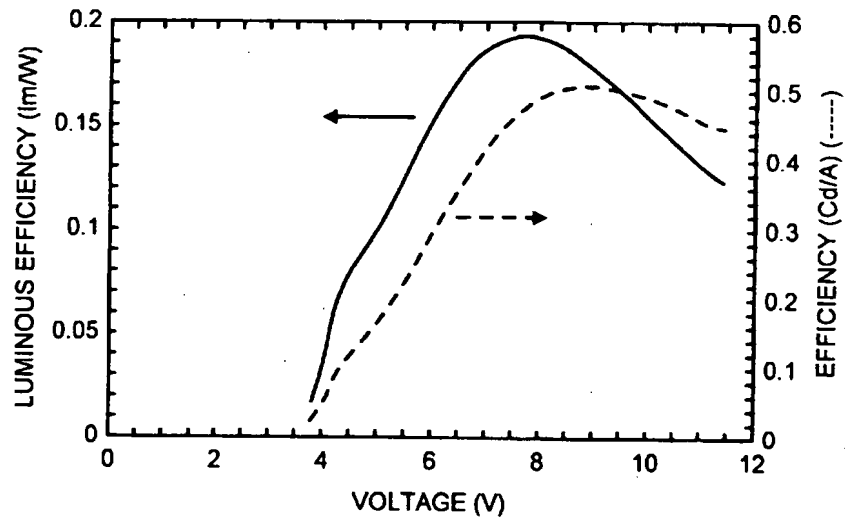


FIG. 21

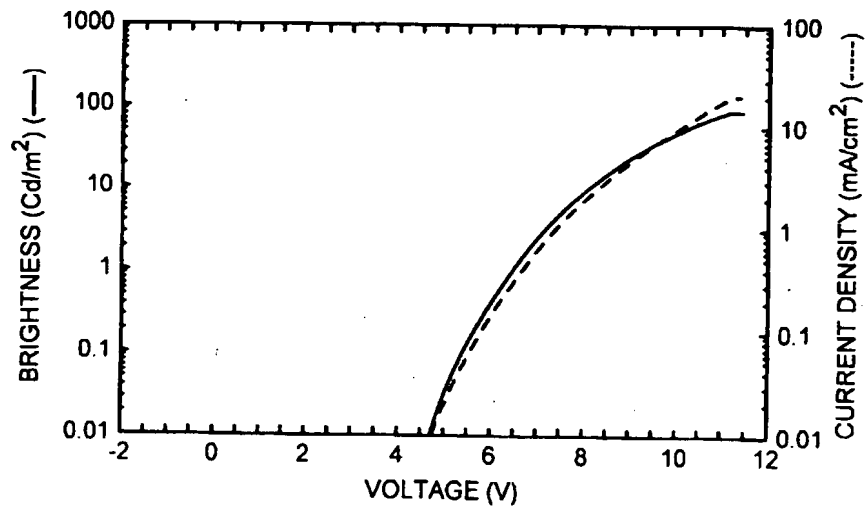


FIG. 22

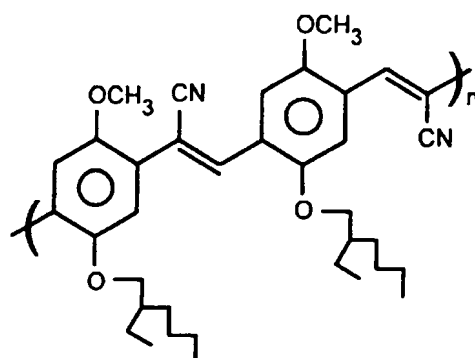


FIG. 23

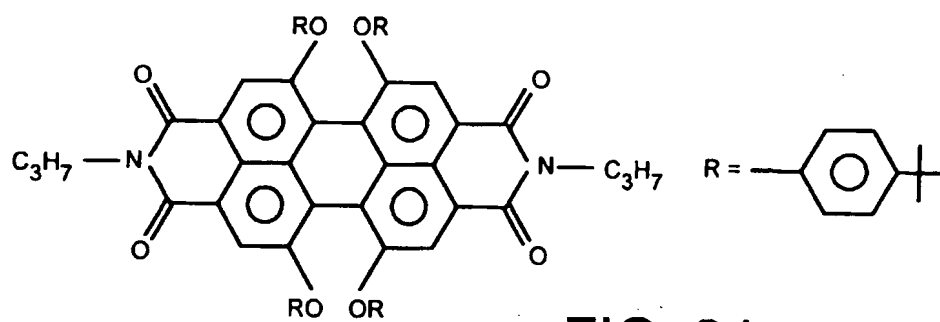


FIG. 24

ORGANIC LIGHT-EMITTERS

This invention relates to light-emissive devices and materials comprising light-emissive organic materials.

Many applications call for a light-emissive device that emits light of a specific colour. Figure 1 shows the 1931CIE diagram of chromaticity with x and y axes plotting the characteristics of different colours. The accepted PAL standard red, green and blue areas are marked at 1, 2 and 3. At 4 a range of standard white colour temperatures from 4000K to 9000K are plotted. There is a particular need for light-emissive devices that emit pure white light in that range.

It is difficult to achieve specific emission colours. One approach to the problem is to use colour filters located between the light emitter and a user to adjust the final colour. Another is to down-convert high energy radiation (e.g. UV or blue) using for example phosphorescence. However, the use of colour filters can reduce the power efficiency of the device. Another approach is to use a combination of several distinct light-emissive pixels. The pixels each emit different colours and are closely set (or even overlapping) so that their emission colours combine to give a viewer the impression of the desired colour. This type of device has the advantage that by altering the light output from the pixels the perceived colour can be changed. However, forming the individual pixels makes the manufacture of such a device complicated, and the light output from each pixel must be carefully controlled to maintain a specific colour.

One emerging class of display devices is those that use an organic material for light emission. Light-emissive organic materials are described in PCT/WO90/13148 and US 4,539,507, the contents of both of which are incorporated herein by reference. The basic structure of these devices is a light-emissive organic layer, for instance a film of a poly(p-phenylenevinylene ("PPV")), sandwiched between two electrodes. One of the electrodes (the cathode) injects negative charge carriers (electrons) and the other electrode (the anode) injects positive charge carriers (holes). The electrons

and holes combine in the organic layer, generating photons. In PCT/WO90/13148 the organic light-emissive material is a polymer. In US 4,539,507 the organic light-emissive material is of the class known as small molecule materials, such as (8-hydroxyquinolino)aluminium ("Alq3"). In a practical device, one of the electrodes is typically transparent, to allow the photons to escape the device.

Figure 2 shows the cross-sectional structure of a typical organic light-emissive device ("OLED"). The OLED is typically fabricated on a glass or plastic substrate 1 coated with a transparent first electrode 2 such as indium-tin-oxide ("ITO"). Such coated substrates are commercially available. This ITO-coated substrate is covered with at least a layer of a thin film of an electroluminescent organic material 3 and a final layer forming a second electrode 4, which is typically a metal or alloy. Other layers can be added to the device, for example to improve charge transport between the electrodes and the electroluminescent material.

Like other devices, organic light-emissive devices also suffer from the difficulty of tailoring emission colours.

According to one aspect of the present invention there is provided a light-emissive device comprising: a first charge carrier injecting layer for injecting positive charge carriers; a second charge carrier injecting layer for injecting negative charge carriers; and a light-emissive layer located between the charge carrier injecting layers and comprising a mixture of at least two electroluminescent organic materials, the relative proportions of the said organic materials in the light-emissive layer influencing the emission colour of the light-emissive layer.

According to a second aspect of the present invention there is provided a method for tailoring the emission colour of a light-emissive material, the method comprising blending a first electroluminescent organic material with a second electroluminescent organic material in a ratio such as to achieve the desired emission colour.

According to a third aspect of the invention there is provided a light-emissive device having a light-emissive layer comprising a light-emissive material formed by a method according to the second aspect of the invention.

Preferably, when the device is in use light emission is from both or at least two of the electroluminescent organic materials. Where the light-emissive layer comprises more than two electroluminescent materials emission may suitably be from three or more, and preferably all, of those materials.

The emission colour of the light-emissive layer is suitably a white colour: either a standard white colour such as white T=6200K, a colour that is substantially a standard white colour or a colour that appears to the human eye to be white. Alternatively the emission colour could be another colour such as red, green or blue or an intermediate hue between, for instance, green and red.

Suitably at least one of the said electroluminescent materials is a red-light-emissive material (i.e. when used in isolation its emission colour appears to the human eye to be red). One example of such a material is perylene monomer (and/or perylene polymer). Other examples are the other red-emissive materials mentioned below.

Suitably at least one of the said electroluminescent materials is a blue-light-emissive material. Examples of such a material are poly (2,7 -(9,9-di-n-octylfluorene)) and poly (2,7-9,9-di-n-hexylfluorene)-1,3-phenylene). Other examples are the other blue-emissive materials mentioned below. One preferred arrangement is for such a blue-emissive component, or more generally the one of the electroluminescent materials with the largest band gap, to be the predominant electroluminescent material in the light-emissive layer.

One more specific example of a suitable light-emissive layer is one that comprises poly (2,7 -(9,9-di-n-octylfluorene)) and poly (2,7-9,9-di-n-hexylfluorene)-1,3-phenylene) and from 1.0 to 1.5% of perylene polymer and/or perylene monomer.

The light-emissive layer may comprise at least one non-electroluminescent and/or non-light-emissive material that influences the emission colour of the light-emissive layer. This material may assist the transport of one or more types of charge carriers and/or assist recombination of charge carriers to generate light.

One, more or preferably all of the electroluminescent materials are suitably polymer materials, preferably semiconductive polymer materials and preferably conjugated (either fully or partially) polymer materials. Alternatively, one or more of the electroluminescent materials could be a non-polymeric organic material, such as a small molecule material, an oligomer material or a monomer material. One suitable arrangement is for at least one of the electroluminescent materials to be a polymer material and for at least one of the electroluminescent materials to be a non-polymer material (e.g. a small molecule, oligomer or monomer material).

The device may suitably include one or more additional layers. One example of such an additional layer is a charge transport layer which could be located between one of the charge carrier injection layers and the light-emissive layer. There could be further charge transport layers located between the light-emissive layer and the same or the other charge carrier injection layer. The or each charge transport layer may suitably comprise one or more polymers such as polystyrene sulphonic acid doped polyethylene dioxythiophene ("PEDOT-PSS"), poly(2,7-(9,9-di-*n*-octylfluorene)-(1,4-phenylene-(4-imino(benzoic acid))-1,4-phenylene-(4-imino(benzoic acid))-1,4-phenylene)) ("BFA"), polyaniline and PPV.

Non-limiting examples of electroluminescent materials that could be used, in any combination, are as follows: poly(p-phenylenevinylene) ("PPV"), poly(2-methoxy-5(2'-ethyl)hexyloxyphenylenevinylene) ("MEH-PPV"), ("MEH-CN-PPV"), one or more PPV-derivatives (e.g. di-alkoxy or di-alkyl derivatives), polyfluorenes and/or co-polymers incorporating polyfluorene segments, PPVs and related co-polymers, poly(2,7-(9,9-di-*n*-octylfluorene)) ("F8"), F8 with anthracene side chains, poly(2,7-(9,9-di-*n*-hexylfluorene)), poly(2,7-9,9-di-*n*-hexylfluorene)-1,3-phenylene), poly(2,7-(9,9-di-*n*-octylfluorene))-(1,4-phenylene-((4-methylphenyl)imino)-1,4-phenylene-((4-methylphenyl)imino)-1,4-phenylene)), poly(2,7-(9,9-di-*n*-octylfluorene))-(1,4-phenylene-((4-methylphenyl)imino)-1,4-phenylene-((4-methoxyphenyl)imino)-1,4-phenylene)), perylene monomer, perylene polymer or small molecule materials such as Alq3.

One of the charge carrier injecting layers (the hole-injecting layer or anode electrode) preferably has a work function of greater than 4.3 eV. That layer may comprise a

metallic oxide such as indium-tin oxide ("ITO") or tin oxide ("TO"). The other charge carrier injecting layer (the electron-injecting or cathode electrode) preferably has a work function less than 3.5 eV. That layer may suitably be made of a metal with a low work function (Ca, Ba, Yb, Sm, Li etc.) or an alloy or multi-layer structure comprising one or more of such metals together optionally with other metals (e.g. Al). At least one of the electrode layers is suitably light transmissive, and preferably transparent, suitably to light emission from the light-emissive regions.

The present invention will now be described by way of example with reference to the accompanying drawings, in which:

figure 3 shows photoluminescence spectra for blends of a first example;

figure 4 is a 1931 CIE chromaticity chart showing the emission colours of blends of the first example;

figure 5 is a 1931 CIE chromaticity chart showing the emission colours of blends of a second example;

figure 6 shows photoluminescence spectra for blends of a third example;

figure 7 is a 1931 CIE chromaticity chart showing the emission colours of blends of the third example;

figure 8 shows electroluminescence spectra for blends of a fourth example;

figure 9 is a 1931 CIE chromaticity chart showing the emission colours of blends of the fourth example;

figure 10 is a 1931 CIE chromaticity chart showing the emission colours of blends of a fifth example;

figure 11 shows electroluminescence spectra for blends of the fifth example;

figure 12 shows electroluminescence spectra for blends of the fifth example;

figure 13 is a 1931 CIE chromaticity chart showing the emission colours of blends of the fifth example;

figures 14 and 15 show photoluminescence spectra for blends of a sixth example;

figure 16 shows the variation of 1931 CIE co-ordinates with varying perylene monomer content in a blend of the sixth example;

figures 17 and 18 are 1931 CIE chromaticity charts showing the emission colours of blends of the sixth example;

figure 19 shows a photoluminescence spectrum for a blend of a seventh example;

figure 20 shows an electroluminescence spectrum for a blend of the seventh example;

figure 21 plots luminous and power efficiency against voltage for a blend of the seventh example;

figure 22 plots brightness and current density against voltage for a blend of the seventh example;

figure 23 shows the chemical formula for MEH-CN-PPV; and

figure 24 shows the chemical formula for PDII (PD standing for perylene derivative): perylene monomer.

A series of example materials and devices have been prepared. The devices were of two types: photoluminescent (PL) devices and electroluminescent (EL) devices.

To form the photoluminescent devices a light-emissive layer (whose composition is described in more detail in each example below) was spin coated on to a glass substrate to a thickness of approximately 100nm.

To form the electroluminescent devices an electron transport layer (whose composition is described in more detail below) was first spun to a thickness of approximately 100nm on to a 12x12mm plane of glass coated with indium-tin oxide (ITO). The transport layer was then baked for 1 hour at 200°C in flowing nitrogen gas. A light-emissive layer was then spin coated to a thickness of approximately 100nm (except where otherwise stated below) over the transport layer and a cathode of either Li:Al (with a 3nm thick layer of lithium followed by a 300nm layer of aluminium) or Ca:Al (with an 80nm layer of calcium followed by a 300nm layer of aluminium) was deposited in an evaporator at a base pressure of approximately 8×10^{-7} mbar. Bond wires were then attached by silver dag to the metal contacts and the device encapsulated in epoxy resin.

The electron transport layers were formed of PEDOT:PSS (with a PEDOT to PSS ratio of 1:3) blended with AP2. The AP2 was present as an adhesion promoter, to increase adhesion between the PEDOT:PSS and the emissive layer.

To form the materials referred to below as blends the components of the blend were mixed together thoroughly.

Materials used in the following examples are as follows:

- F8: poly (2,7 -(9,9-di-n-octylfluorene)) [blue-emissive]
- F8A: F8 with anthracene side chains (random copolymer with 15% anthracene) [blue-emissive]
- F6: poly (2,7 -(9,9-di-n-hexylfluorene)) [blue-emissive]
- F6M: poly (2,7-9,9-di-n-hexylfluorene)-1,3-phenylene) [blue emissive]
- PFM: poly (2,7 -(9,9-di-n-octylfluorene))-(1,4-phenylene-((4-methylphenyl)imino)-1,4-phenylene-((4-methylphenyl)imino)-1,4-phenylene)) [blue-emissive]
- PFMO: poly (2,7 -(9,9-di-n-octylfluorene))-(1,4-phenylene-((4-methylphenyl)imino)-1,4-phenylene-((4-methoxyphenyl)imino)-1,4-phenylene)) [blue-emissive]
- MEH-CN-PPV: (see figure 23) [red-orange-emissive]
- Perylene monomer: N,N'-Dipropyl-1,6,7,12-tetrakis(4-tert-butylphenoxy)-3,4:9,10-perylene tetracarboxdiimide (see figure 24) [red-emissive]
- Perylene polymer [red-emissive]
- PEDOT:PSS: polystyrene-sulphonate doped polyethylene dioxythiophene
- TFB: poly (2,7 -(9,9-di-n-octylfluorene))-(1,4-phenylene-((4-sec butylphenyl)imino)-1,4-phenylene
- BFE: poly (2,7 -(9,9-di-n-octylfluorene))-(1,4-phenylene-((4-carboethoxyphenyl)imino)-1,4-phenylene((4-carboethoxyphenyl)imino)-1,4-phenylene))
- AP2: (3-Glycidoxypropyl)-trimethoxysilane ($C_9H_{20}O_5Si$)

Example 1 - F8 + MEH-CN-PPV

Devices were prepared in which the emissive layers were formed from blends of:

1. F8 with
2. MEH-CN-PPV.

Figure 3 shows the photoluminescence spectra of devices with emissive layers of from 0% MEH-CN-PPV (i.e. pure F8) to 50% MEH-CN-PPV. Figure 4 shows the emission colours of devices with emissive layers of 0%, 1%, 2% and higher percentages of MEH-CN-PPV.

The results indicate that the emission spectrum of MEH-CN-PPV is strongly blue-shifted when diluted in F8. For MEH-CN-PPV concentrations greater than around 5% the MEH-CN-PPV spectrum dominates the emission, whereas blue emission from the F8 is strongly suppressed. Upon reducing the MEH-CN-PPV concentration further the red spectra are strongly blue shifted and the F8 blue emission increases in intensity. As the MEH-CN-PPV emission shifts towards shorter wavelengths the blue and red spectra merge, resulting in light emission over a broad range of wavelengths.

This blend shows potential for use as a material for emitting white light. Figure 4 shows that at a MEH-CN-PPV concentration of less than 1% the blend's colour should be close to an acceptable white emission (white 6200K at $x \approx 0.32$, $y \approx 0.32$). To improve the white colour further the F8 could be substituted by another light-emissive polymer with a blue emission colour that is close to or even bluer than the colour of the PAL blue region as indicated in figure 2.

Example 2 - F8:7TFB:10PFMO + MEH-CN-PPV

Devices were prepared in which the emissive layers were formed from blends of:

1. a blend of F8 with 7% TFB (referred to as 7TFB) and 10% PFMO (referred to as 10PFMO) with
2. MEH-CN-PPV.

Figure 5 shows the photoluminescent emission colours of devices with emissive layers of 0%, 0.195%, 0.39%, 0.78%, 1.56%, 3.13% and higher percentages of MEH-CN-PPV.

The results indicate that there is little difference in emission characteristics between this system and that of example 1. The CIE results and the trend in

photoluminescence emission colours with variation in concentration are similar for examples 1 and 2.

Example 3 - F8A:7TFB:10PFMO + MEH-CN-PPV

Devices were prepared in which the emissive layers were formed from blends of:

1. a blend of F8A with 7% TFB and 10% PFMO with
2. MEH-CN-PPV.

Figure 6 shows the photoluminescence spectra of devices with emissive layers of from 0.1% MEH-CN-PPV to 3.13% MEH-CN-PPV. Figure 7 shows the emission colours of devices with emissive layers of 0% to 3.13% and higher percentages of MEH-CN-PPV.

The results indicate that the emission spectrum of the blend changes from a red-dominated spectrum at MEH-CN-PPV concentrations of, for instance, around 3% to a blue-dominated spectrum at lower concentrations of MEH-CN-PPV, for instance around 0.1%.

Comparing the results with those of example 2 it can be seen that the change in host from F8 to F8A does not substantially affect the photoluminescence emission colour of the blend around the white colour region. However, the blend containing F8A has some practical advantages: F8A is more thermally stable than F8.

Example 4 - F8A:7TFB:10PFMO + MEH-CN-PPV

Electroluminescent devices were prepared in which the emissive layers were formed from blends of:

1. a blend of F8A with 7% TFB and 10% PFMO with
2. MEH-CN-PPV.

Li:Al cathodes were used.

Figure 8 shows the photoluminescence (PL) spectra of devices with emissive layers from 0.25% MEH-CN-PPV to 1.0% MEH-CN-PPV and with an applied voltage of approximately 14V. Figure 9 shows the emission colours of the same devices.

A comparison of figures 7 and 9 shows that the CIE co-ordinates for the electroluminescent devices are shifted in the y-axis compared to those for the photoluminescent devices. The general appearance of the emission colours for the electroluminescent devices is somewhat green/off-white rather than white. It was also found that during a prolonged test the emission colours of the electroluminescent devices of example 4 shifted slightly but progressively higher in their y-co-ordinates.

Example 5 - F6M/F8A:7TFB:15PFM + Perylene monomer/F8BT

Electroluminescent and photoluminescent devices were prepared in which the emissive layers were formed from blends of:

1. a blend of F6M or F8A with 7% or 10% TFB (indicated by 7TFB or 10TFB) and 10% or 15% PFM (indicated by 10PFM or 15PFM) with
2. one or both of perylene monomer and F8BT.

Figure 10 shows the photoluminescence colours of devices whose emissive layers had compositions in the following systems:

1. F8A:7TFB:15PFM with 0.1% perylene monomer and from 0.04% to 0.38% and higher percentages of F8BT (shown at 10);
2. F8A:7TFB:15PFM with 1% perylene monomer and a range of percentages of F8BT (shown at 11);
3. F8A:7TFB:15PFM with 0% to 1.6% and higher percentages of perylene monomer (shown at 12).

Figure 11 shows the electroluminescence spectra of devices whose emissive layers had compositions of F6M:10TFB:10PFM with 0.1% to 0.8% perylene monomer. The devices had Li:Al cathodes.

Figure 12 shows the electroluminescence spectra of devices whose emissive layers had compositions of F6M:10TFB:10PFM with 0.2% perylene monomer and 0.05% to 1% F8BT.

Figure 13 shows the electroluminescence colours of devices whose emissive layers had compositions in the following systems:

1. F6M:7TFB:10PFM with perylene monomer (the emissive layer in this case was approximately 36nm thick) (shown at 20);
2. F6M:7TFB:10PFM with from 0.1% to 0.8% perylene monomer (the emissive layer in this case was approximately 73nm thick) (shown at 21);
3. F8A:7TFB:15PFM with from 0.1% to 0.8% perylene monomer (shown at 22);
4. F6M:7TFB:10PFM with 0.28% perylene monomer and a range of percentages of F8BT (shown at 23);
5. F8A:7TFB:15PFM with 0.2% perylene monomer and a range of percentages of F8BT (shown at 24).

Figures 10 to 13 indicate that upon diluting the perylene monomer with F8A:7TFB:15PFM the proportion of blue and red emission in the PL and EL spectra changes, and there is an almost linear shift in the CIE x and y co-ordinates from those of perylene to those of F8A:7TFB:15PFM. Since the PL maxima of perylene and F8A lie at approximately 630nm and 450nm respectively the blend's colour may be further adjusted by adding a yellow emitting polymer (in this example F8BT, which has an emission maximum at around 540nm, mid-way between those of the red and blue components). The results show that by varying these three components the x and y CIE co-ordinates of the emission colour can be tuned.

When the blends are used in EL devices the y CIE co-ordinate of devices incorporating F8A is found to be greater than when used in a PL device. However, devices incorporating F6M instead of F8A retain smaller y CIE co-ordinates. Figure 13 shows that the trend of the emission colours of the devices whose emissive layers comprised F6M:7TFB:10PFM with perylene monomer (the emissive layer being approximately 73nm thick) is towards the point of white (T=6200K) (shown at 25 in figure 13). Devices of this system would therefore be expected to give a good white emission colour.

Example 6 - F6M:10TFB:10PFM/F6:10BFE:10PFM + Perylene monomer

Electroluminescent and photoluminescent devices were prepared in which the emissive layers were formed from blends of:

1. a blend of F6M with 10% TFB and 10% PFM or a blend of F6M with 10% BFE and 10% PFM with
2. perylene monomer.

Figure 14 shows the photoluminescence spectra of two devices, one having an emissive layer of a blend of F6:10BFE:10PFM with 2% perylene and the other having an emissive layer of a blend of F6M:10TFB:10PFM with 2% perylene.

Figure 15 shows the photoluminescence spectra of devices having emissive layers of blends of F6M:10TFB:10PFM with from 0.6% to 1.8% perylene.

Figure 16 plots the x and y CIE co-ordinates for emission colours of blends of F6M:10TFB:10PFM with from 0% to 3.2% perylene against the percentage of perylene in the blends.

Figure 17 shows the photoluminescence colours of devices with emissive layers of blends of F6M:10TFB:10PFM with perylene monomer.

Figure 18 shows the photoluminescence (at 30) and electroluminescence (at 31) colours of devices with emissive layers of blends of F6:10BFE:10PFM with perylene monomer.

F6M has polymer chains with broken conjugation resulting from meta linkages, which are absent in F6. However, figure 14 shows that the PL spectra of the two polymers are similar.

Figure 17 shows that for a blend of F6M:10TFB:10PFM with 1.2% perylene (shown at 30) the x CIE co-ordinate is close to that of a white colour of T=6200K. In this blend the intensities of emission from the F6M and perylene components are

approximately equivalent. However, the y CIE co-ordinate is below that of white T=6200K, and the observed colour is rather violet.

Figure 18 shows that the PL and EL emission colours for the F6:10BFE:10PFM + perylene system are similar, with EL emission occurring at only slightly greater x and y co-ordinates.

Example 7 - F6:10BFE:10PFM + Perylene monomer

Electroluminescent and photoluminescent devices were prepared in which the emissive layers were formed from blends of:

1. a blend of F6 with 10% BFE and 10% PFM_with
2. perylene monomer.

A blend of F6 with 10% BFE and 10% PFM (F6:10BFE:10PFM) was prepared. To this was added 1% of perylene monomer. The photoluminescence of the material was found to give CIE co-ordinates of $x=0.461$, $y=0.317$. To move the emission closer to a desirable white colour more F6:10BFE:10PFM was added in order to raise the x CIE component. This dilution reduced also the y CIE component to around 0.28. In order to raise the y CIE component BFE was added. This produced the blend whose photoluminescence spectrum is shown in figure 19. The CIE co-ordinates of the emission colour were $x=0.307$ and $y=0.311$, very close to the target of white T=6200K. The emission spectrum includes regions that appear to derive from F6 (indicated at 40), BFE/PFM (41) and perylene monomer (42). Figure 20 shows the electroluminescence of a device whose emissive layer was of the same blend. The CIE co-ordinates of the emission colour were $x=0.298$ and $y=0.361$: the emission colour looked white to the eye. It appears that whilst the lower wavelength components from the F6 emission have been reduced in intensity compared to the EL spectrum of figure 19 the relative intensities of the F6 and perylene components have been altered. The device was found to have a maximum luminous efficiency of 0.2Lm/W and to emit 100Cd/m² at approximately 10V (with a luminous efficiency of around 0.15Lm/W). Figure 21 plots luminous efficiency (Lm/W) and power efficiency (Cd/A) for such a device against applied voltage. Figure 22 plots brightness and

current density for such a device against applied voltage. The devices whose characteristics are shown in figures 21 and 22 had Ca:Al cathodes.

General Considerations

Many variations could be made to the devices described in the above examples. For example, different electrode or charge transport materials could be used, other blends or blends of other materials could be used for the light-emissive layers; additional layers, especially additional charge transport layers, could be used; and different fabrication methods could be employed. One specific variation is to substitute perylene monomer for perylene polymer, in the same or different amounts.

The present invention may include any feature or combination of features disclosed herein either implicitly or explicitly or any generalisation thereof, irrespective of whether it relates to the presently claimed invention. In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention.

CLAIMS

1. A light-emissive device comprising:
 - a first charge carrier injecting layer for injecting positive charge carriers;
 - a second charge carrier injecting layer for injecting negative charge carriers;and
 - a light-emissive layer located between the charge carrier injecting layers and comprising a mixture of at least two electroluminescent organic materials, the relative proportions of the said organic materials in the light-emissive layer influencing the emission colour of the light-emissive layer.
2. A light-emissive device as claimed in claim 1, wherein in use light emission is from both the electroluminescent organic materials.
3. A light-emissive device as claimed in claim 1 or 2, wherein the emission colour of the light-emissive layer is a white colour.
4. A light-emissive device as claimed in any preceding claim, wherein at least one of the said electroluminescent materials is a red-light-emissive material.
5. A light-emissive device as claimed in any preceding claim, wherein at least one of the said electroluminescent materials is a blue-light-emissive material.
6. A light-emissive device as claimed in any preceding claim, wherein the light-emissive layer comprises perylene polymer and/or perylene monomer.
7. A light-emissive device as claimed in any preceding claim, wherein the light-emissive layer comprises poly (2,7 -(9,9-di-n-octylfluorene)) and/or poly (2,7-9,9-di-n-hexylfluorene)-1,3-phenylene).
8. A light-emissive device as claimed in claim 7 as dependent on claim 6, wherein the light-emissive layer comprises from 1.0 to 1.5% of perylene polymer and/or perylene monomer.

9. A light-emissive device as claimed in any preceding claim, wherein the light-emissive layer comprises at least one non-electroluminescent material that influences the emission colour of the light-emissive layer.
10. A light-emissive device as claimed in any preceding claim, wherein each electroluminescent material is a polymer material.
11. A light-emissive device as claimed in claim 10, wherein each electroluminescent material is a semiconductive polymer material.
12. A light-emissive device as claimed in claim 10 or 11, wherein each electroluminescent material is a conjugated polymer material.
13. A light-emissive device as claimed in any preceding claim, comprising a charge transport layer between one of the charge injection layers and the light-emissive layer.
14. A method for tailoring the emission colour of a light-emissive material, the method comprising mixing a first electroluminescent organic material with a second electroluminescent organic material in a ratio such as to achieve the desired emission colour.
15. A method as claimed in claim 14, wherein at least one of the said electroluminescent materials is a polymer material.
16. A light-emissive material formed by the method of claim 14 or 15.
17. A light-emissive device substantially as herein described with reference to the accompanying drawings.
18. A light-emissive material substantially as herein described with reference to the accompanying drawings.



The Patent Office

Application No: GB 9818376.7
Claims searched: 1-18

Examiner: SJ Morgan
Date of search: 3 December 1998

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H1K(KEAM)

Int Cl (Ed.6): H01L 51/20; H05B 33/14

Other: Online:WPI, JAPIO, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	WO 95/31515 A1 (FORSKARPATENT) See whole document.	1-5 & 10-16
X	US 5 276 381 (PIONEER) See whole document.	1, 2, & 10-13
X	JP 9 219 289 A (CHISSO) See abstract.	1-5 & 10-16

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.